THE BASAL METABOLISM OF MATURE CHICKENS AND THE NET-ENERGY VALUE OF CORN[1]

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INTRODUCTION

One of the great contributions of Armsby to the science of animal nutrition was the demonstration that the requirements of animals for nutrients, and the values of feeds in covering these requirements, are two separate and distinct problems, requiring different experimental methods for their solution. The requirement of an animal for energy, for example, must involve a study of the heat production of the animal and of the energy content of animal tissues and secretions produced during growth, fattening, egg production, gestation, and lactation. The energy requirements are, therefore, best expressed in terms referring to the animal rather than to the feed; hence the measurement of animal requirements in terms of feed or digestible nutrients is an incomplete and an inaccurate measurement, however valuable it may be in practical animal husbandry.

According to Armsby (*1*),[2] the measurement of the true value of feeds as sources of energy to animals involves a determination of the energy content of the feed and of all losses of energy incurred in its utilization by the animal. If the latter are subtracted from the former, the "net-energy" value of the feed is obtained. A more complete definition of the actual energy value of a feed to the animal has never been proposed, nor one of greater significance as a guide to experimental investigation. It would seem that the same conception might be applied to other nutrients.

WORK OF OTHER INVESTIGATORS

While considerable work has been done upon the net-energy value of feeds for steers, practically no work of this character has been done with reference to other farm animals. The present investigation was undertaken as an initial study of the utilization of feed energy by chickens.

Gerhartz in 1914 reported (*2*) an extensive investigation on two hens concerned with the energy required in egg production. As one phase of the investigation some consideration was given to the question of the "work of digestion" of food, i. e., the loss of food energy as heat during digestion and assimilation. Upon comparing the increase in heat production of hens during a day in which food was consumed over that during a day of fast, with the intake of nutrients, Gerhartz concluded that Zuntz's factors for the estimation of the "work of digestion" could be applied to chickens.[3] However, the conclusion appears to be very poorly supported by the experimental data compared, since on the days of fast the heating effect of the

[1] Received for publication Feb. 3, 1927; issued July, 1927.
[2] Reference is made by number (italic) to "Literature cited," p. 943.
[3] Zuntz's factors (*2, p. 189*) obtained upon mammals are: 0.8 calorie per gram of protein consumed, 0.24 calorie per gram of fat, and 0.4 calorie per gram of carbohydrate.

meal consumed on the preceding evening can not be regarded as having been entirely dissipated in 10 to 20 hours, while on the days of feeding the full heating effect of the food can not be assumed to have been obtained in an experimental period of less than 12 hours' duration. In one of the feeding periods the hen consumed an egg laid only three hours before the termination of the respiration period; nevertheless, the full heating effect of the contained nutriment is assumed to have been obtained. In view of these facts, the close agreement that Gerhartz obtained in two comparisons between the observed increases in heat production and those computed by means of the Zuntz factors applied to the nutrients consumed must be considered purely fortuitous.

Hâri (*4*) and Hâri and Kriwuscha (*5*) have made observations on the heating effect of corn upon ducks and geese. Using the values obtained by direct calorimetry, the results may be summarized as shown in Table 1.

TABLE 1.—*The heating effect of corn on ducks and geese, as summarized from the experiments of Hári, and of Hári and Kriwuscha*

Bird	Body weight	Corn consumed	Heat production per day	Estimated basal heat production	Heating effect of corn	
					Observed	Calculated to 100 grams of corn
	Grams	*Grams*	*Calories*	*Calories*	*Calories*	*Calories*
Goose A	3, 541	50	196	175	21	42
	3, 499	100	274	172	102	102
	2, 505	100	225	138	87	87
Goose B	3, 126	50	241	153	88	176
	3, 126	100	233	152	81	81
Duck A	967	50	127	90	37	74
Duck B	860	50	111	69	42	84

It is evident that the results obtained, calculated to 100 grams of corn, exhibited a rather wide variability, precluding any satisfactory estimate of a representative average.

In the same investigations the gross energy of food and solid and liquid excreta was determined, permitting an estimation of the metabolizable energy of corn for geese and ducks. The data covering metabolizable energy are summarized in Table 2.

TABLE 2.—*Metabolizable energy of corn for geese and ducks, as summarized from the experiments of Hári, and of Hári and Kriwuscha*

Bird	Body weight	Corn consumed	Gross energy of corn	Gross energy of excreta	Metabolizable energy of corn in—	
					Total calories	Percentage of gross energy
	Grams	*Grams*	*Calories*	*Calories*		
Goose A	3, 541	50	202	38	164	81
	3, 499	100	403	68	335	83
	2, 505	100	403	80	323	80
Goose B	3, 126	50	202	38	164	81
	3, 126	100	403	65	338	84
Duck A	967	50	195	78	117	60
Duck B	860	50	195	75	120	62

For geese 82 per cent of the gross energy of corn appears to be metabolizable, while for ducks the much lower average of 61 per cent was obtained on two birds.

THE METABOLIZABLE ENERGY IN CORN

The first step in the present investigation was the determination of the metabolizable energy of corn. Results were obtained for 10 hens, 8 of which were Rhode Island Reds and 2 were White Plymouth Rocks. After several days' feeding of a constant amount of ground corn, the preliminary period being generally more than 10 days in length, the hens were placed in small cages, wire-mesh floors and movable pans being placed underneath for the collection of the excreta. The collection periods were seven days in length. The complete data resulting from this test are given in Table 3.

TABLE 3.—*Metabolizable energy of corn for hens*

Bird No.[a]	Average body weight	Average daily food	Daily energy intake	Energy of excreta per day	Metabolizable energy		
					Per day	Per 100 grams of corn	In terms of gross energy
	Grams	*Grams*	*Calories*	*Calories*	*Calories*	*Calories*	*Per cent*
129	2,126	44	181	28	153	348	84
130	1,610	44	181	31	150	341	83
132	1,407	42	172	30	142	338	83
135	1,732	44	181	31	150	341	83
74	2,144	50	196	32	164	328	84
129a	2,269	50	196	34	162	324	83
85	2,243	75	294	55	239	319	81
151	2,531	75	294	50	244	325	83
1		50	201	35	166	332	83
2	2,810	50	203	43	160	320	79

[a] Birds Nos. 1 and 2 were White Plymouth Rocks; the others were Rhode Island Reds.

The metabolizable energy of corn is taken as the difference between its gross-energy content and the gross energy contained in the excreta resulting from its digestion and assimilation. No correction has been made for the nitrogen balances of the birds. Such a correction is always small and can not be made with any great degree of accuracy, particularly with birds. It is also assumed that no appreciable amount of combustible gases is produced in the digestive tract of the chicken. The gross energy of the corn and excreta was determined in the Parr oxygen bomb calorimeter.

The percentage of the gross energy of corn that was metabolizable proved to be very constant, averaging 83.

All of the samples of corn used in these experiments were, unfortunately, not analyzed. However, that used for hens Nos. 74, 129a, 85, and 151 was found to contain 89.5 per cent dry matter, 3.49 per cent fat, and 1.56 per cent nitrogen, and to possess a gross-energy content of 3.917 calories per gram. The small variation in the composition of the samples of corn obtained for experimental work in this laboratory could hardly be considered as exerting any influence upon the percentage of its gross energy that would be metabolizable.

THE BASAL METABOLISM OF MATURE CHICKENS

Having determined the fraction of the gross energy of corn that is metabolizable, the next step in the investigation was to determine the basal heat production of mature chickens and the increase in heat production due to the consumption of corn. This heat increment represents a fraction of the metabolizable energy of corn that is inevitably wasted as heat. It is, therefore, just as surely an energy loss as the energy in the indigestible portion of the corn contained in the feces or that in the unoxidizable portion contained in the urine. Its determination is essential in arriving at a value for the net-energy content of corn.

The determination of heat production evidently requires the use of an animal calorimeter or respiration apparatus. In all of their calorimetric work on chickens the writers have used the gravimetric respiration apparatus of Haldane (*3*), as described and pictured in a previous publication from this laboratory (*10*). The writers have found that the method is simple of operation when its requirements have been carefully studied, economical of time, readily checked for possible errors, and capable of yielding consistent and accurate results except possibly for short observational periods. In the present investigation the observational periods were generally 22 to 23 hours in length. The weighing of the bottles and the feeding and watering of the chickens occupied the remaining one or two hours of the day. The rate of ventilation was approximately two liters per minute.

The heat production has been computed on the assumption that the total respiratory quotient is nonprotein. This method of calculation does not consider protein metabolism. However, from the data of Zuntz and Schumburg (*7, p. 62; 12*), relating to the calorific value of a liter of oxygen used in the combustion of the different nutrients, it may be computed that the maximum error in the total heat production figures resulting from this simplification is 6.58 per cent, and that the usual error would be less than 2 per cent.[4]

Total respiratory quotient	Maximum percentage of protein metabolism possible	Calorific value of a liter of O_2	Maximum error in assuming 100 per cent non-protein metabolism
0.75	44.65	4.594	3.06
.80	100.00	4.485	6.58
.85	73.12	4.624	4.92
.90	47.30	4.765	3.23
.95	22.97	4.906	1.58

Thus, if the total respiratory quotient is 0.85 and the protein metabolism is at its maximum (73.12 per cent of total calories), the error in neglecting the protein metabolism entirely would be less than 5 per cent. Under the much more usual conditions where the protein metabolism never exceeds 25 per cent of the total the error for all respiration quotients would be less than 1.5 per cent.

In the use of this or any other calorimetric method the temperature in the animal chamber must be under observation and should preferably be under control. During the daytime this could be

[4] Taking the calorific values of a liter of oxygen used in the combustion of protein, fat, and carbohydrate to be 4.485 calories, 4.686 calories, and 5.047 calories, respectively, the following is true:

accomplished readily. In view of the fact that the average critical temperature for Rhode Island Red hens is 62° (*10*), particular care was taken in this study that the temperature of the laboratory did not fall below 70° F. At night, however, control was not so effective, and occasionally the temperature fell considerably below 70°. A maximum and minimum thermometer was kept in the animal chamber in such position that its glass parts did not come in contact with the bird. The records read from this thermometer have been reported with all experiments.

The muscular activity of the chickens was also under continuous observation. The respiration chamber was suspended from a spring of such size that any considerable movement of the bird would result in an up-and-down movement of the chamber. This was recorded by a homemade "work adder" which revolved in only one direction. The record was, of course, purely of relative significance and served to assure the comparability of experimental periods as far as concerned the activity of the birds under observation. The animal chamber was not sufficiently large to permit of much movement, and the absolute darkness prevailing inside also tended to discourage much activity in the chicken. The work records have not been reported since (1) they indicate in general no great disproportion in activity among comparable experimental periods, (2) in the few cases in which a disproportionately large record was obtained the heat production of the bird was not out of line with that of comparable periods, and (3) the record has no definite or absolute significance with regard to the amount of movement within the chamber.

At the beginning it was considered necessary to determine how soon after feeding the heat production of the chicken returns to the basal level. From a large number of observations it was evident that, although the basal level was often reached after a fasting period of 24 hours, a fast of 48 hours was required before the basal level was reached in all cases. As illustrative of this finding, the data given in Table 4 are presented.

TABLE 4.—*Heat production of hens following the feeding of 75 grams of corn*

	Hen 2353				Hen 2001				Hen 200			
Day	Weight	Minimum and maximum temperature of chamber	Respiratory quotient	Heat production	Weight	Minimum and maximum temperature of chamber	Respiratory quotient	Heat production	Weight	Minimum and maximum temperature of chamber	Respiratory quotient	Heat production
	Grams			*Calories*	*Grams*			*Calories*	*Grams*			*Calories*
1	2,200	90–91	0.89	212	3,667	83–90	0.92	195	2,530	85–88	0.91	166
2	2,133	81–84	.94	153	3,533	82–90	.80	156	2,385	82–87	.79	[a] 144
3	2,047	85–90	.70	149	3,505	75–80	.69	151	2,287	80–93	.71	115
4	1,942	85–94	.72	[a] 154	3,463	70–86	.69	154	2,262	80–86	.71	110
5	1,897	89–95	.74	[b] 151	3,415	85–89	.70	134	2,230	77–87	.70	106

[a] Hen laid an egg weighing 52 gm. in respiration chamber.
[b] Eggshell found in respiration chamber. Apparently the hen had eaten contents.

TABLE 5.—*Basal heat production of mature chickens*

Bird No.	Date	Body weight	Body surface	Minimum and maximum temperature of chamber	Basal heat production per day			Respiratory quotient
					Total	Per kilogram of body weight	Per square meter of body surface	
Hens:		*Grams*	*Sq. cm.*		*Calories*	*Calories*	*Calories*	
E605	Nov. 9, 1925	1,925	1,551	63–70	126	65.5	812	0.70
	Nov. 17, 1925	1,880	1,533	62–80	132	70.2	861	.73
	Nov. 20, 1925	1,820	1,509	72–82	119	65.4	789	.71
	Dec. 4, 1925	1,715	1,464	72–82	100	58.3	683	.70
	Dec. 11, 1925	1,675	1,447	74–82	101	60.3	698	.70
	Dec. 14, 1925	1,630	1,428	72–78	88	54.0	616	.75
542	Sept. 28, 1925	1,790	1,496	70–82	109	60.9	729	.72
	Oct. 7, 1925	1,770	1,488	65–73	106	59.9	712	.71
	Oct. 10, 1925	1,740	1,475	63–71	102	58.6	692	.72
	Oct. 15, 1925	1,705	1,460	64–70	91	53.4	623	.71
	Oct. 18, 1925	1,645	1,434	54–62	90	54.7	628	.70
	Nov. 2, 1925	1,880	1,533	70–78	89	47.3	581	.73
	Nov. 5, 1925	1,880	1,533	71–76	91	48.4	594	.73
158 [a]	Jan. 29, 1923	1,657	1,379	67–75	94	56.7	682	.70
	Feb. 1, 1923	1,630	1,359	74–78	81	49.8	595	.80
132 [a]	Feb. 5, 1923	1,520	1,302	66–72	90	59.2	691	.70
	Feb. 8, 1923	1,525	1,304	72–80	82	53.8	629	.87
200	June 17, 1925	2,287	1,666	80–93	115	50.3	690	.71
	June 29, 1925	2,300	1,670	66–84	110	47.8	659	.71
	July 2, 1925	2,265	1,657	82–99	109	48.1	658	.71
	Sept. 7, 1925	1,990	1,554	80–89	103	51.8	663	.72
	Sept. 17, 1925	2,010	1,561	73–84	103	51.2	660	.70
	Sept. 20, 1925	1,990	1,554	69–79	92	46.2	592	.73
	Sept. 27, 1925	1,955	1,540	73–77	89	45.5	578	.72
	Oct. 11, 1925	1,895	1,516	62–66	102	53.8	673	.70
	Oct. 14, 1925	1,825	1,488	64–66	99	54.3	665	.65
A552	July 6, 1925	2,055	1,603	82–94	119	57.9	742	.70
	July 9, 9125	2,027	1,592	84–86	114	56.2	716	.72
2429 [a]	July 20, 1925	1,860	1,490	78–82	113	60.8	758	.70
	July 23, 1925	1,809	1,462	69–81	112	61.9	766	.71
546	Oct. 19, 1925	2,050	1,577	60–70	139	67.8	881	.71
	Oct. 25, 1925	2,020	1,565	68–74	120	59.4	767	.71
	Oct. 28, 1925	1,965	1,544	72–76	113	57.5	732	.72
	Nov. 3, 1925	1,900	1,518	67–75	110	57.9	725	.70
	Nov. 6, 1925	1,860	1,502	72–78	106	57.0	706	.70
35	Nov. 16, 1925	2,140	1,645	65–74	103	48.1	626	.71
	Nov. 23, 1925	2,115	1,636	58–72	102	48.2	623	.70
	Nov. 26, 1925	2,090	1,626	75–82	102	48.8	627	.72
	Dec. 4, 1925	2,100	1,632	74–84	85	40.5	520	.70
2420	Dec. 4, 1924	2,578	2,116	78–85	113	43.8	534	.72
2058	Dec. 11, 1924	2,195	1,759	80–92	122	55.6	694	.72
0	May 20, 1925	1,983	1,885	72–78	116	58.5	615	.69
2353	June 3, 1925	2,047	1,915	85–90	149	[b](72.8)	[b](778)	.70
2001	June 10, 1925	3,505	2,632	75–80	151	43.1	574	.69
Cocks:								
443 [a]	Aug. 25, 1924	2,750	1,933	78–88	148	53.8	766	.72
	Aug. 28, 1924	2,700	1,910	80–86	138	51.1	723	.69
458 [a]	Sept. 8, 1924	2,900	2,003	70–74	166	57.2	829	.70
	Sept. 11, 1924	2,800	1,957	72–82	154	55.0	787	.71
2284 [a]	Sept. 15, 1924	3,600	2,314	68–80	154	42.8	666	.72
	Sept. 18, 1924	3,450	2,249	68–76	166	48.1	738	.71
225 [a]	Sept. 22, 1924	3,235	2,155	68–82	191	59.0	886	.73
	Sept. 25, 1924	3,040	2,067	74–84	162	53.3	784	.72
161 [a]	Sept. 22, 1924	3,120	2,103	70–94	182	58.3	865	.71
	Sept. 25, 1924	2,945	2,024	73–93	173	58.7	855	.71
180 [a]	Aug. 18, 1924	2,330	1,731	73–84	127	54.5	734	.68
	Aug. 21, 1924	2,275	1,704	80–90	114	50.1	669	.72
552 [a]	Aug. 25, 1924	2,475	1,802	78–91	138	55.8	766	.73
	Aug. 28, 1924	2,410	1,771	72–88	131	54.4	739	.71

[a] The surface area of these birds was estimated by the Meeh formula (*9*), taking $k=9.85$. The surface area of all other birds was estimated from the weight and the rump-to-shoulder distance, according to the formula

$$S=5.86\ W^{0.5}\ L^{0.6}$$

of Mitchell, Card, and Hamilton (*11, p. 84*). Although this formula was obtained from White Plymouth Rock birds, it was shown to apply also to Rhode Island Red hens.

[b] Obtained during a period of egg production.

On the first experimental day these three Rhode Island Red hens were given a feeding of 75 gm. of ground corn before being placed in the respiration chamber; the heat production was then determined on five successive days in observational periods of 7 to 8 hours, the results being expressed on the 24-hour basis. In the case of hen 2353 the basal level was apparently established in 24 hours, but the fact that she was producing eggs possibly kept her heat production at a high level on the third and fourth days. The basal level was not reached with hen 200 and, less certainly with hen 2001, until they had fasted 48 hours. Many other experiments to be cited later support the conclusion that a hen can not be considered to be in the postabsorptive state until 48 hours have elapsed since the last feeding.

Before considering the experiments dealing with the heat increment due to feeding it is interesting to consider the results obtained on the basal heat production of Rhode Island Red chickens. Such data, collected from the feeding experiments, are reported in Table 5. The values obtained refer to the heat production after a 48-hour fast, observed in periods of 19 to 23 hours and expressed on the 24-hour basis. The results have also been expressed in calories per day per kilogram of body weight and per square meter of body surface (skin area).

Where more than one basal metabolism determination has been made upon a chicken the results have been arranged in the order in which they were obtained. It will be noted that in general a decrease in basal metabolism occurs during the course of a series of observations, particularly well shown with hens 542, 546, and E605. This decrease is probably comparable to that observed by Lusk and Du Bois (*8*) in dogs during a series of laboratory experiments and seems to be due to confinement and the resulting lowering of vitality. While there may be some suspicion that some of the results obtained are larger than the actual basal values because of exposure for short periods at night to environmental temperatures below the critical, the large majority of the heat productions do not appear to be complicated by this factor.

A number of other basal metabolism data on Rhode Island Red chickens are available from studies in which, for one reason or another, the heating effect of corn was not satisfactorily determined. The majority of these results were obtained at a time when the method of studying the effect of feeds on metabolism was being developed, and represent either initial determinations or, as in most cases, determinations after a three-day experimental period. They have been assembled in Table 6.

The homogeneity of the results given in Tables 5 and 6 is somewhat disturbed by the fact that the basal metabolism of the chickens in general decreased with the time spent on experiment. Hence, the average for a hen kept on experiment for a long period of time would not be comparable to that of a hen on experiment for a short period of time. A more significant average would, therefore, be obtained from the results secured in the first metabolism experiments on the birds, representing, as nearly as possible, their basal metabolism at the time of removal from the poultry farm.

TABLE 6.—*Basal heat production of a group of Rhode Island Red chickens*

Bird No.	Date	Body weight	Body surface [a]	Minimum and maximum temperature of chamber	Basal heat production per day			Respiratory quotient
					Total	Per kilogram of body weight	Per square meter of body surface	
		Grams	*Sq. cm.*		*Calories*	*Calories*	*Calories*	
Hens:								
230	Oct. 23, 1924	1,937	1,531	74–92	114	58.9	745	0.72
2217	Oct. 9, 1924	2,720	1,919	78–88	128	47.1	667	.72
2089	Oct. 16, 1924	2,490	1,810	74–84	127	51.0	702	.71
137	do	2,330	1,731	70–80	117	50.2	676	.71
91	Oct. 23, 1924	2,025	1,577	70–89	116	57.3	736	.76
2429	Oct. 30, 1924	1,940	1,532	77–87	117	60.3	764	.74
2076	do	2,132	1,632	76–86	124	58.2	760	.73
2053	Nov. 6, 1924	2,300	1,716	76–86	129	56.1	752	.72
2013	Nov. 13, 1924	2,295	1,714	76–84	130	56.6	759	.72
2160	do	2,242	1,687	76–86	113	50.4	670	.72
2210	Nov. 26, 1924	1,845	1,482	68–85	84	45.5	567	.87
2353	do	1,705	1,406	70–93	106	62.2	754	.72
200	Dec. 4, 1924	2,445	1,788	72–90	115	47.0	643	.74
2009	Dec. 11, 1924	2,405	1,768	74–90	119	49.5	673	.71
127	Jan. 26, 1923	2,138	1,635	60–78	101	47.2	618	.73
73	Feb. 12, 1923	2,575	1,851	66–82	160	62.1	864	.72
Cocks:								
174	Sept. 1, 1924	2,475	1,802	72–84	150	60.6	832	.67
	Sept. 4, 1924	2,400	1,766	74–82	124	51.7	702	.72
816	Sept. 1, 1924	2,812	1,962	76–88	187	66.5	953	.72
	Sept. 4, 1924	2,700	1,910	73–78	164	60.7	859	.71
328	Sept. 11, 1924	2,820	1,966	71–77	151	53.5	768	.72
316	Sept. 15, 1924	3,290	2,179	66–90	228	69.3	1,046	.70
	Sept. 18, 1924	3,085	2,087	68–80	196	63.5	939	.69
524	Oct. 2, 1924	3,125	2,105	68–90	178	57.0	846	.72
541	do	2,740	1,929	70–86	141	51.5	731	.73
721	July 21, 1924	2,475	1,803	76–88	146	59.0	810	.73
	July 24, 1924	2,400	1,766	81–82	112	46.7	634	.73
398	July 31, 1924	2,650	1,886	80–88	131	49.4	695	.68
474	Aug. 7, 1924	3,000	2,049	76–88	148	49.3	722	.73
524	Aug. 11, 1924	3,030	2,063	77–84	160	52.8	776	.68
	Aug. 14, 1924	2,970	2,035	72–80	155	52.2	762	.70
427	Aug. 11, 1924	3,010	2,054	72–78	158	52.5	769	.69
	Aug. 14, 1924	2,960	2,031	72–82	147	49.7	724	.71
446	Aug. 18, 1924	3,185	2,132	72–82	180	56.5	844	.68
	Aug. 21, 1924	2,900	2,003	82–90	186	64.2	929	.71

[a] The surface area of these birds was estimated by the Meeh formula (*9*), taking $k=9.85$.

Considering only the first successful determinations made upon the birds, preceded at most by three days' confinement in the respiration apparatus, the average basal heat production for the 28 hens was 54.9 calories per day per kilogram of body weight, or 703 calories per day per square meter of body surface. For the 19 cocks the averages were 55.7 calories and 806 calories, respectively. These results indicate a distinct sex difference in basal metabolism, in agreement with work upon other animals. The standard deviations of the individual determinations were 6.64 calories per kilogram body weight, and 81.5 calories per square meter body surface for the hens and 5.76 calories and 88.2 calories for the cocks. The coefficients of variation were 12.1 per cent on the body weight and 11.6 per cent on the body surface in the case of the hens and 10.3 per cent on the body weight and 10.9 per cent on the body surface in the case of the cocks. These coefficients of variation may be compared with those computed by Harris and Benedict (*6*) for human subjects. For men the coefficients found were 9.36 for the basal metabolism referred to weight and 8.05 for the basal metabolism referred to surface. For women the coefficients were 14.14 and 9.17, respectively.

The average respiratory quotient in the experiments reported in Table 5 was 0.713, and in the experiments reported in Table 6, 0.719. Evidently the metabolism of the chicken in the period from the forty-eighth to the seventieth hours after feeding is almost entirely at the expense of fat. While a small minority of the individual quotients were below the respiratory quotient for fat, such deficits are quite probably due to slight errors in the oxygen determinations and are so considered in the calculation of the heat production. The writers did not obtain the consistently low values for the quotient during fast reported by Gerhartz (*2*) in experiments on hens. The results of the broader but contradictory experience of the writers, as well as the inherent improbability of the general occurrence of conditions that would force the respiratory quotient to 0.65, 0.60, or lower values in short periods of fast, may well indicate that these low values are due to technical errors.

The basal heat production of hens just considered refers to the nonlaying hen. The only comparable values that have been found in the literature are those of Gerhartz (*2*) upon two hens. The basal heat production in three experiments for one of these hens, in a period of sexual inactivity, 13 to 23 hours after feeding, was found to be 584, 681, and 676 calories daily per square meter of body surface as computed by the Meeh formula (*9*) where $k = 9.49$. In the brooding period this hen gave values of 785 and 779 calories and another hen values of 917 and 795 calories. All of these values are quite within the range of variation found in the writers' experiments. Hâri (*4*) has reported average basal heat production values of 698 and 1,036 calories per day per square meter of body surface for two geese; and Hâri and Kriwuscha (*5*) values of 735 and 901 calories for two ducks.

According to Gerhartz, the hen producing eggs has a much larger basal metabolism than the nonlaying hen, a difference (increase) of 44 per cent being noted in one hen. Although the writers obtained their data largely from nonlaying hens, occasionally an egg was laid during an experimental observation. In Table 4 the egg production of hen 2353 apparently increased her basal heat production, since at the end of 48 hours of fast it amounted to 72.8 calories per day per kilogram, or 778 calories per day per square meter of body surface. (See Table 5.) The apparently large heating effect of 75 gm. of corn with hen 200 (Table 4) is also plausibly explained by the production of an egg on the second day of the experiment. On the other hand, in experiment 21 on hen A552 (see Table 9) the production of an egg on the seventh day of the experiment did not appear to disturb the level of heat production, nor was the estimated heating effect of the corn excessive, even though the basal value, 716 calories per day per square meter of surface, was near the average for all of the hens. The subject evidently requires further investigation, particularly since there is no obvious reason why egg production in the hen, any more than milk production in the cow, should increase the basal metabolism and the maintenance requirement.

THE HEATING EFFECT OF CORN

The corn used in the respiration experiments to determine the heat increment due to feeding was analyzed from time to time, with the results shown in Table 7.

TABLE 7.—*Chemical composition of corn used in respiration experiments*

Sample No.	Percentage of—						Gross energy (calories per gram)
	Dry matter	Crude protein	Nitrogen-free extract	Crude fiber	Fat	Ash	
1	91.2	10.0	73.9	2.68	3.27	1.38	4.10
2	92.4	8.3	76.1	2.99	3.70	1.35	4.10
3	92.1	9.7	74.1	2.86	3.99	1.39	4.13
4	87.9	9.0	73.2	2.18	2.19	1.33	3.78
5	89.9	8.8	73.5	2.69	3.74	1.19	3.99
Average	90.7	9.16	74.2	2.68	3.38	1.33	4.02

In view of the small variation among these analyses, particularly with reference to dry matter, it was not considered necessary to relate definite samples with definite experiments. The respiration experiments to be described may therefore be considered to relate to corn containing 91 per cent of dry matter and 4.02 calories of gross energy per gram.

In the first series of experiments on the heating effect of corn the plan was to determine the basal metabolism of the chicken after a 48-hour fast, to give 50 or 75 gm. of ground corn in one feeding at the beginning of the second experimental day, and to determine the 24-hour heat production on the day of feeding and on the two following days. The last day's result, obtained after 48 hours of fast, was considered to represent the basal metabolism. It was, in general, lower than the result of the first basal period. The increase in heat production due to the feeding of corn was computed by assuming that the decrease in basal metabolism, whenever such occurred, was linear. Where the variation in the weight of the bird was considerable this factor also was considered in estimating the basal metabolism on the day of feeding and on the following day. The total heating effect per 100 gm. of corn was then computed as the final result in each experiment. Before each day's experiment the chicken was given 50 c. c. of water by pipette. The results of 20 experiments of this type upon 15 Rhode Island Red chickens are summarized in Table 8.

TABLE 8.—*Heating effect of corn on mature chickens (one feeding)*

Experiment No.	Bird No.	Day of test	Weight of bird	Treatment	Minimum and maximum temperature of chamber	CO_2 given off per 24 hours	O_2 per 24 hours	Respiratory quotient	Heat production per 24 hours	Estimated basal heat production	Effect of corn: Observed	Effect of corn: Calculated to 100 grams of corn
			Gms.			*Gms.*	*Gms.*		*Calories*	*Calories*	*Calories*	*Calories*
Hens:												
1	546	1	2,020	Fasted 48 hours	68–74	35.9	36.5	0.71	120			
		2	2,030	Fed 75 gm. corn	62–70	60.7	42.6	1.03	151	118	33	
		3	2,020	Fasted	70–74	38.7	37.6	.75	125	116	9	56
		4	1,965	do	72–76	34.0	34.4	.72	113			
2	546	1	1,900	Fasted 48 hours	67–75	32.3	33.4	.70	110			
		2	1,895	Fed 50 gm. corn	68–78	49.8	37.3	.97	131	109	22	
		3	1,895	Fasted	70–74	34.8	34.1	.74	113	108	5	54
		4	1,860	do	72–78	31.1	32.2	.70	106			
3	E605	1	1,880	Fasted 48 hours	62–80	39.9	39.9	.73	132			
		2	1,880	Fed 75 gm. corn	70–78	59.6	43.6	.99	154	128	26	
		3	1,875	Fasted	72–78	39.6	37.7	.76	126	123	3	40
		4	1,820	do	72–82	35.4	36.4	.71	119			
4	E605	1	1,675	Fasted 48 hours	74–82	29.5	30.8	.70	101			
		2	1,675	Fed 50 gm. corn	72–82	42.3	31.7	.97	111	97	14	
		3	1,670	Fasted	73–85	29.8	27.7	.78	93	92	1	30
		4	1,630	do	72–78	27.3	26.6	.75	88			
5	542	1	1,705	Fasted 48 hours	64–70	27.1	27.8	.71	91			
		2	1,710	Fed 50 gm. corn	62–65	41.0	30.7	.97	108	91	17	
		3	1,690	Fasted	58–66	29.8	28.0	.77	94	90	4	42
		4	1,645	do	54–62	26.2	27.3	.70	90			
6	542	1	1,880	Fasted 48 hours	70–78	26.9	26.9	.73	89			
		2	1,930	Fed 75 gm. corn	69–79	47.7	34.9	.99	123	90	33	
		3	1,945	Fasted	70–80	38.2	31.6	.88	108	90	18	68
		4	1,880	do	71–76	27.9	27.6	.73	91			
7	158	1	1,657	Fasted 48 hours	67–75	27.2	28.6	.70	94			
		2	1,686	Fed 75 gm. corn	66–80	42.4	31.5	.98	111	90	21	
		3	1,700	Fasted	74–82	40.1	28.4	1.03	100	86	14	47
		4	1,630	do	74–78	26.6	24.2	.80	81			
8	132	1	1,521	Fasted 50 hours	66–72	26.2	27.4	.70	90			
		2	1,553	Fed 75 gm. corn	72–76	41.2	31.0	.96	109	87	22	
		3	1,572	Fasted		38.5	29.4	.95	103	84	19	55
		4	1,525	do	72–80	28.9	24.1	.87	82			
9	200	1	2,300	Fasted 46 hours	66–84	31.5	32.1	.71	110			
		2	2,317	Fed 75 gm. corn	74–86	50.2	38.3	.95	134	110	24	
		3	2,330	Fasted	78–88	43.0	36.3	.86	124	110	14	51
		4	2,265	do	82–99	32.5	33.2	.71	109			
10	A552	1	2,055	Fasted 46 hours	82–94	34.9	36.3	.70	119			
		2	2,063	Fed 75 gm. corn	82–92	50.4	37.8	.97	132	117	15	
		3	2,065	Fasted	82–88	43.8	38.2	.83	130	116	14	40
		4	2,027	do	84–86	34.3	34.5	.72	114			
11	2429	1	1,860	Fasted 48 hours	78–82	33.1	34.4	.70	113			
		2	1,857	Fed 75 gm. corn	74–88	48.1	37.1	.94	129	112	17	
		3	1,864	Fasted	68–83	43.1	36.7	.86	125	112	13	40
		4	1,809	do	69–81	33.3	34.0	.71	112			
12	35	1	2,115	Fasted 48 hours	58–72	30.1	31.1	.70	102			
		2	2,140	Fed 75 gm. corn	76–80	52.1	36.4	1.04	129	102	27	
		3	2,135	Fasted	74–79	36.6	31.5	.84	107	102	5	43
		4	2,090	do	75–82	30.6	30.9	.72	102			
13	200	1	2,010	Fasted 48 hours	73–84	30.4	31.5	.70	103			
		2	2,035	Fed 75 gm. corn	80–87	51.4	36.2	1.03	129	99	30	
		3	2,040	Fasted	80–88	37.9	32.0	.86	109	95	14	59
		4	1,990	do	69–79	28.1	28.0	.73	92			
Cocks:												
14	443	1	2,750	Fasted 48 hours	78–88	44.5	45.1	.72	148			
		2	2,720	Fed 75 gm. corn	80–88	62.0	50.2	.90	173	145	28	
		3	2,760	Fasted	80–90	48.1	47.5	.74	157	142	15	57
		4	2,700	do	80–86	40.0	42.0	.69	138			
15	552	1	2,475	Fasted 48 hours	78–91	42.2	41.7	.73	138			
		2	2,445	Fed 75 gm. corn	82–90	64.2	52.3	.89	180	136	44	
		3	2,475	Fasted	77–93	42.4	42.2	.73	139	134	5	65
		4	2,410	do	72–88	39.0	39.8	.71	131			
16	458	1	2,900	Fasted 48 hours	70–74	48.8	50.7	.70	166			
		2	2,900	Fed 75 gm. corn	72–80	69.9	55.0	.92	191	162	29	
		3	2,845	Fasted	70–82	49.4	49.4	.72	163	158	5	45
		4	2,800	do	72–82	45.8	46.9	.71	154			
17	2,284	1	3,600	Fasted 48 hours	68–80	46.0	46.8	.72	154			
		2	3,515	Fed 75 gm. corn	72–84	70.3	54.4	.94	189	158	31	
		3	3,520	Fasted	66–80	53.8	51.8	.75	172	162	10	55
		4	3,450	do	68–76	49.5	50.5	.71	166			

TABLE 8.—*Heating effect of corn on mature chickens (one feeding)*—Continued

Experiment No.	Bird No.	Day of test	Weight of bird	Treatment	Minimum and maximum temperature of chamber	CO_2 given off per 24 hours	O_2 per 24 hours	Respiratory quotient	Heat production per 24 hours	Estimated basal heat production	Effect of corn: Observed	Effect of corn: Calculated to 100 grams of corn
			Gms.			*Gms.*	*Gms.*		*Calories*	*Calories*	*Calories*	*Calories*
18	225	1	3,235	Fasted 48 hours	68–82	57.9	57.9	0.73	191			
		2	3,150	Fed 75 gm. corn	70–80	74.8	61.4	.89	211	181	30	
		3	3,100	Fasted	71–81	62.2	55.0	.82	186	171	15	60
		4	3,040	do	74–84	48.6	49.2	.72	162			
19	161	1	3,120	Fasted 48 hours	70–94	54.4	55.4	.71	182			
		2	3,080	Fed 75 gm. corn	66–78	76.1	65.6	.84	223	179	44	
		3	3,000	Fasted	70–76	62.0	57.4	.78	192	176	16	(93)
		4	2,945	do	73–93	51.8	52.7	.71	173			
20	180	1	2,330	Fasted 48 hours	73–84	36.2	38.6	.68	127			
		2	2,275	Fed 75 gm. corn	76–82	57.1	43.2	.96	151	123	28	
		3	2,275	Fasted	78–86	41.6	39.4	.77	131	119	12	53
		4	2,275	do	80–90	34.3	34.5	.72	114			

Another method of attacking the same problem is to compare the level of heat production established by the continuous feeding of a constant amount of corn with the basal heat production. In this type of experiment the basal metabolism was determined after 48 hours of fast, after which the chickens were given 50 or 75 gm. of ground corn and an adequate and constant amount of water early each morning. The heat production was determined daily until, for several consecutive days, a level appeared to have been established, following which food was withdrawn and a basal determination again made after a fast of 48 hours. The heating effect of the corn fed was then taken as the difference between the average heat production on feed and the average estimated basal heat production. Eleven experiments of this type upon five different Rhode Island Red hens are summarized in Table 9.

TABLE 9.—*Heating effect of corn on hens (continuous feeding)*

Experiment No.	Bird No.	Day of test	Weight of bird	Treatment	Minimum and maximum temperature of chamber	CO_2 given off per 24 hours	O_2 consumption per 24 hours	Respiratory quotient	Heat production per 24 hours	Average heat production on feed	Estimated basal heat production	Effect of corn: Observed	Effect of corn: Calculated to 100 grams
			Grams			*Gms.*	*Gms.*		*Calories*	*Calories*	*Calories*	*Calories*	*Calories*
21	A552	1	2,027	Basal	84–86	34.3	34.5	0.72	114				
		5	2,210	Fed 75 gm. corn	77–91	57.2	42.7	.97	150				
		6	2,170	do	76–84	68.0	47.2	1.05	168				
		[a] 7	2,157	do	84–88	58.4	44.6	.95	156				
		8	2,135	do	81–97	68.3	45.5	1.09	163	159	122	37	50
22	546	1	2,050	Basal	60–70	41.4	42.3	.71	139				
		3	2,095	Fed 75 gm. corn	64–86	71.9	48.4	1.08	173				
		4	2,100	do	68–87	69.3	47.0	1.07	168				
		5	2,105	do	69–85	68.6	46.5	1.07	166	169	133	36	48
		7	2,020	Basal	68–74	35.9	36.5	.71	120				

[a] Hen laid an egg (45 gm.) in respiration chamber.

TABLE 9.—*Heating effect of corn on hens (continuous feeding)*—Continued

Experiment No.	Bird No.	Day of test	Weight of bird	Treatment	Minimum and maximum temperature of chamber	CO_2 given off per 24 hours	O_2 consumption per 24 hours	Respiratory quotient	Heat production per 24 hours	Average heat production on feed	Estimated basal heat production	Effect of corn: Observed	Effect of corn: Calculated to 100 grams
			Grams			*Gms.*	*Gms.*		*Calories*	*Calories*	*Caes rilo-*	*Calories*	*Calories*
23	546	1	1,965	Basal	72–76	34.0	34.4	0.72	113				
		3	1,950	Fed 50 gm. corn	68–76	53.7	40.4	.96	142				
		4	1,950	do	68–72	55.2	41.0	.98	144				
		5	1,955	do	70–76	55.9	40.6	1.00	143	143	112	31	62
		7	1,900	Basal	67–75	32.3	33.5	.70	110				
24	E605	1	1,925	do	63–70	37.2	38.3	.70	126				
		3	1,955	Fed 75 gm. corn	68–82	62.2	43.9	1.03	156				
		4	1,965	do	76–79	63.3	44.0	1.04	157				
		5	1,975	do	68–80	66.7	44.6	1.09	160				
		6	1,980	do	74–78	64.2	44.0	1.06	157				
		7	1,975	do	62–76	64.2	44.2	1.06	159	158	129	29	39
		9	1,880	Basal	62–80	39.9	39.9	.73	132				
25	E605	1	1,820	do	72–82	35.4	36.4	.71	119				
		3	1,840	Fed 50 gm. corn	54–72	56.0	40.6	1.00	143				
		4	1,830	do	54–77	51.7	40.0	.94	139				
		5	1,835	do	74–98	51.3	37.9	.98	134	138	119	19	38
		6	1,855	do	76–84	50.6	38.8	.95	135				
26	E605	1	1,715	Basal	72–82	29.3	30.5	.70	100				
		3	1,740	Fed 50 gm. corn	70–82	46.8	34.2	.99	121				
		4	1,755	do	70–84	48.7	34.6	1.02	123				
		5	1,750	do	76–84	47.5	34.6	1.00	122				
		6	1,745	do	74–94	49.6	35.6	1.01	126	123	101	22	44
		8	1,675	Basal	74–82	29.5	30.8	.70	101				
27	542	1	1,790	do	70–82	32.7	33.1	.72	109				
		6	1,835	Fed 75 gm. corn	68–75	59.5	40.1	1.00	142				
		7	1,830	do	65–75	60.9	39.3	1.13	141				
		8	1,830	do	68–76	59.9	40.1	1.09	143	142	108	34	45
		10	1,770	Basal	65–73	31.4	32.3	.71	106				
28	542	1	1,740	do	63–71	30.6	30.9	.72	102				
		2	1,730	Fed 50 gm. corn	63–73	44.3	33.6	.96	118				
		3	1,735	do	65–71	47.6	32.6	1.06	116				
		4	1,735	do	68–70	46.9	33.0	1.03	117	117	96	21	42
		6	1,705	Basal	64–70	27.1	27.8	.71	91				
29	35	1	2,140	do	65–74	30.5	31.4	.71	103				
		3	2,180	Fed 75 gm. corn	70–77	65.0	44.0	1.07	157				
		4	2,165	do	70–78	66.8	46.2	1.05	165				
		5	2,165	do	76–78	66.6	44.4	1.09	159				
		6	2,170	do	70–76	65.7	44.8	1.06	159	160	105	55	73
		8	2,115	Basal	58–72	30.1	31.1	.70	102				
30	200	1	1,990	do	80–89	31.0	31.4	.72	103				
		3	2,017	Fed 75 gm. corn	80–89	62.9	41.0	1.11	147				
		4	2,045	do	80–86	63.4	41.6	1.11	149				
		5	2,070	do	80–82	68.9	43.4	1.15	157				
		6	2,070	do	74–78	67.9	46.4	1.06	(165)				
		7	2,080	do	74–79	65.6	42.3	1.13	152				
		8	2,080	do	73–79	62.3	40.9	1.11	147				
		9	2,080	do	72–77	62.5	41.2	1.10	148	150	106	44	59
		11	2,010	Basal	73–84	30.4	31.5	.70	103				
31	200	1	1,990	do	69–79	28.1	28.0	.73	92				
		2	1,985	Fed 50 gm. corn	65–72	45.5	35.6	.93	123				
		3	2,000	do	65–70	54.2	38.2	1.03	(136)				
		4	2,000	do	65–75	49.7	35.3	1.02	125				
		5	2,000	do	62–76	49.9	35.6	1.02	126				
		6	2,000	do	62–73	49.0	34.7	1.02	123	124	91	33	66
		8	1,955	Basal	73–77	26.6	27.0	.72	89				

In considering these two sets of data it is well at the start to determine how homogeneous they are, particularly with respect to (1) the type of experiment and (2) the amount of food given. Disregarding the exceptionally high result of experiment 19 in the first series of experiments, there were 16 involving a feeding of 75 gm. of corn and only 3 involving a feeding of 50 gm. The average heating effect of corn per 100 gm. was in the first case 52 calories and in the second case 42 calories, the average for the entire series being 50 calories. Among the second series of experiments there were 6 involving a feeding of 75 gm. portions of corn and 5 involving a feeding of 50 gm. portions. The average heating effects were, respectively, 52 calories and 50 calories per 100 gm. of corn; and for the entire group 51 calories. From these averages it may be concluded, in the first place, that the two types of experiments gave essentially the same results. In the early experiments the heating effect extended over two days; animals fed 75 gm. of corn excreted on an average 70 per cent of the extra heat on the day of feeding and 30 per cent on the day following, while animals fed 50 gm. portions excreted on an average 85 per cent the first day and only 15 per cent on the day following. In the second series of experiments, therefore, the level of heat production established by continuous feeding must have exceeded that established by one feeding by exactly the "carry-over" effect of the day following one feeding.

In the second place, the above averages indicate that the smaller portion of corn *may* have had a slightly smaller heating effect per 100 gm. than the larger, but it is evident from an inspection of the tables that the data are too few and too variable to establish the significance of the average differences obtained.

Hence, the data may be considered and treated as a homogeneous series as far as these possible vitiating factors are concerned. It is true that where several tests were made upon the same bird there is some indication of rather distinct individual differences, as the summary in Table 10 shows.

TABLE 10.—*Difference among individual birds in the heating effect of corn per 100 gm.*

Bird No.	Experiment No.	Heat increment per 100 gm. of corn	Bird No.	Experiment No.	Heat increment per 100 gm. of corn
546	1	56	542	5	42
	2	54		6	68
	22	48		27	45
	23	62		28	42
E605	3	40	A552	10	40
	4	30		21	50
	24	39	200	9	51
	25	38		13	59
	26	44		30	59
				31	66
			35	12	43
				29	73

The results obtained with hen 200 are quite sharply distinguished from those obtained with hen E605. Hen 546, except for one of the four experiments, gave higher results than the average, and hen 542, except for one result, gave lower figures than the average. These differences are undoubtedly a source of heterogeneity. However, in view of the number of results obtained and the many other uncontrolled factors that were evidently operating in determining the estimated heating effect of corn, the effect of these differences is probably not serious.

The results of seven experiments upon cocks are summarized in Table 8. Omitting the anomalous result of experiment 19, the average heating effect of corn was 56 calories per 100 gm. For the 13 results on hens the average was 48 calories. The slight difference may be of significance in indicating a smaller heating effect for hens, but the data are too few and variable to permit a definite conclusion on this interesting point.

It is necessary to inquire whether the low minimum temperatures of the animal chamber prevailing at some period during the night in several of the experiments might not have operated in vitiating the estimated heat effect of corn on the metabolism of the chickens. The effect of temperatures below the critical would be to raise the heat production above the level that would otherwise prevail. For any low temperature the effect, if existent, would be more marked in the basal periods than in the feeding periods, since the critical temperature in the basal periods would be higher. Hence, where low temperatures exert such a vitiating effect the result would always be to depress the estimated heat increment below the actual. It is extremely doubtful whether on any of the feeding days the temperature in the chamber ever was less than the critical temperature of the fed bird.

It has been shown elsewhere by the writers (*10*) that the average critical temperature of the fasting Rhode Island Red hen is 62° F., though individual hens may show considerable variability in this respect. There were six experiments in which at least one of the two basal periods possessed a minimum temperature of 62° or below. The average estimated heat increment for these six experiments was 47, as compared with the average of 51 for the entire investigation. Among the six results is included the highest value, 73, obtained in this study, disregarding the anomalous result of experiment 19. The two lowest found, 30 and 38 (experiments 4 and 25), were obtained under temperature conditions above suspicion.

In this connection a further study of Table 10 is of interest. The lowest result for hen 546 is open to suspicion because of a minimum temperature of 60° F. in one of the basal periods, while for hen 542 the three low results may be considered suspicious for the same reason. However, for hen 35 no such explanation of the low value is plausible, while the relative constancy in results for hens E605 and 200 was obtained in spite of a wide variety of temperature conditions.

While it appears, therefore, that some of the low estimates of the heating effect of corn may have been occasioned in part by the prevalence during a fraction of the basal periods of temperatures below the critical, it may readily be shown that such temperature effects were not of serious moment. Eliminating the results of experiment 19 and of 6 experiments in which, for at least one of the basal periods, the minimum temperature was 62° F. or below, gives an average result for the remaining 24 experiments of 52 calories per 100 gm. of corn. If 8 experiments in which, for at least one of the basal periods, the minimum temperature was 65° or below are disregarded, the average result of the remaining 22 experiments is 52 calories per 100 gm. of corn. If the process of elimination is carried further to include all experiments in which the minimum temperature was 70° or below for at least one of the basal periods the average of the remaining 9 experiments becomes 48 calories.

The average heating effect of corn for all 30 experiments (excluding No. 19) is 50.7 ± 1.2 calories per 100 gm. of corn. The standard deviation of the individual determinations is 10.04 calories, and the coefficient of variation 19.8 per cent.

THE NET-ENERGY VALUE OF CORN FOR MATURE CHICKENS

Summing up the results of the investigation, it has been found that 83 per cent of the gross energy of ground corn is metabolizable by chickens and that the average heating effect of corn on cocks and nonlaying hens is 51 calories per 100 gm. The corn used in these investigations contained 402 calories per 100 gm. Its metabolizable energy would, therefore, be 334 calories and its net energy $334 - 51 = 283$ calories per 100 gm., or 1,285 calories per pound. Since the corn used in this investigation contained an average of 91 per cent of dry matter, the net-energy value of corn is 3,110 calories per kilogram of dry matter, or 1,412 calories per pound of dry matter. The latter figure may be compared with the value Armsby gives (*1, p. 660, 722*) for cattle, 926 calories per pound of dry matter, and his estimate for swine, i. e., 1,355 calories. Evidently the nonlaying hen ranks high in her ability to convert the energy of corn to her own uses.

SUMMARY

In experiments upon 10 chickens it has been found that 83 per cent of the gross energy of ground corn is metabolizable.

The average basal heat production of 28 nonlaying hens was found to be 54.9 calories per day per kilogram body weight and 703 calories per day per square meter body surface. For 19 mature cocks the average values found were 55.7 and 806 calories, respectively. These values may be considerably reduced during protracted confinement in the laboratory. The basal metabolism of hens is apparently raised considerably during periods of egg production, though this question requires much further study.

In 30 experiments upon 15 mature Rhode Island Red chickens an average heating effect of 50.7 ± 1.2 calories per 100 gm. of corn (91 per cent dry matter) has been obtained. After a single feeding of 75 gm. of ground corn an average of 70 per cent of the extra heat is eliminated during the first 24 hours and 30 per cent during the second 24 hours. For a single feeding of 50 gm. of corn 85 per cent of the extra heat is excreted in 24 hours and 15 per cent in the second 24-hour period. The chicken, therefore, can not be considered to be in the postabsorptive condition until more than 24 hours have elapsed since the last feeding. After 48 hours this condition may be considered to have been established. Some evidence was obtained indicating that the heating effect of corn is slightly greater with cocks than with hens.

The net-energy value of corn for mature chickens has been found to be 3,110 calories per kilogram of dry matter, or 1,412 calories per pound of dry matter.

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